

# **A review of the $\alpha_s$ measurements at LEP**

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## Scale definition

- The  $\beta$  function:

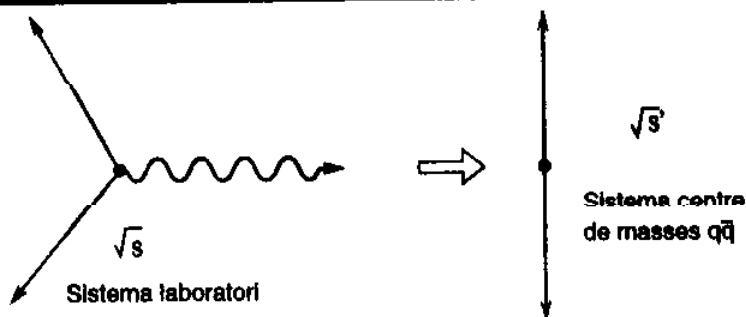
$$\mu \frac{d\alpha_s(\mu)}{d\mu} = -\frac{\beta_0}{2\pi}\alpha_s^2(\mu) - \frac{\beta_1}{4\pi^2}\alpha_s^3(\mu) + \mathcal{O}(\alpha_s^4)$$

At LEP, we have access to several energy scales:

- LEP I
  - $\alpha_s$  measurements at  $\mu = M_Z$
  - $\alpha_s$  measurements at  $\mu = m_\tau$  from  $\tau$  decays
- LEP II  $\Rightarrow \mu = 130, 136, 161, 172$  GeV

- inclusive quantities:  $R_h$ ,  $R_T$
- global event shapes
- scaling violations
- 3-jet rate
- measurements with  $q\bar{q}\gamma \Rightarrow$  running of  $\alpha_s$
- $\alpha_s$  universality
- $\alpha_s(m_T)$
- $\alpha_s$  in LEP II  $\Rightarrow$  running of  $\alpha_s$

## $\alpha_s$ measurements with $q\bar{q}\gamma$



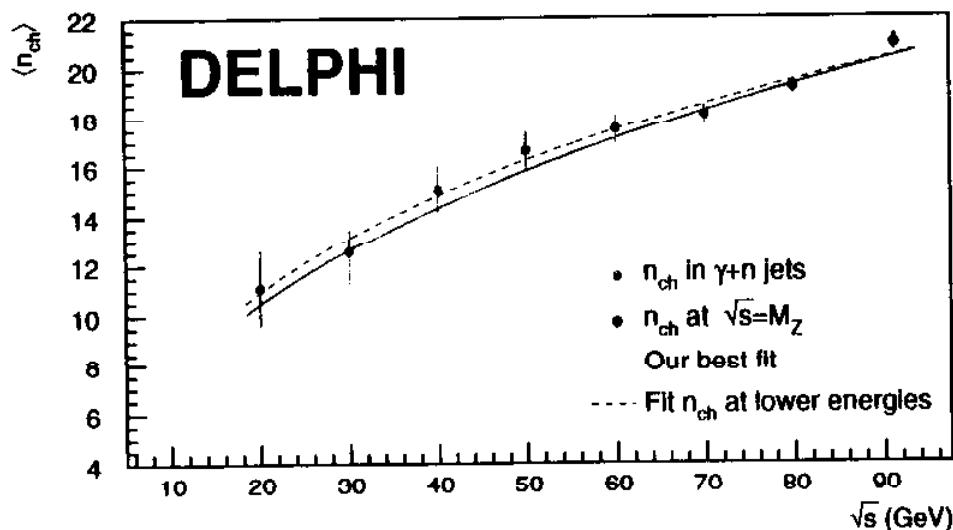
Fitting  $\alpha_s$

$\langle n_{ch}(\sqrt{s}) \rangle$  distribution allows fitting  $\alpha_s$  (MLLA):

$$\langle n \rangle = a \alpha_s^b \exp(c/\sqrt{\alpha_s})(1 + \mathcal{O}(\sqrt{\alpha_s}))$$

$$b = \frac{1}{4} + \frac{10}{27} \frac{N_f}{\beta_0} \approx 0.49$$

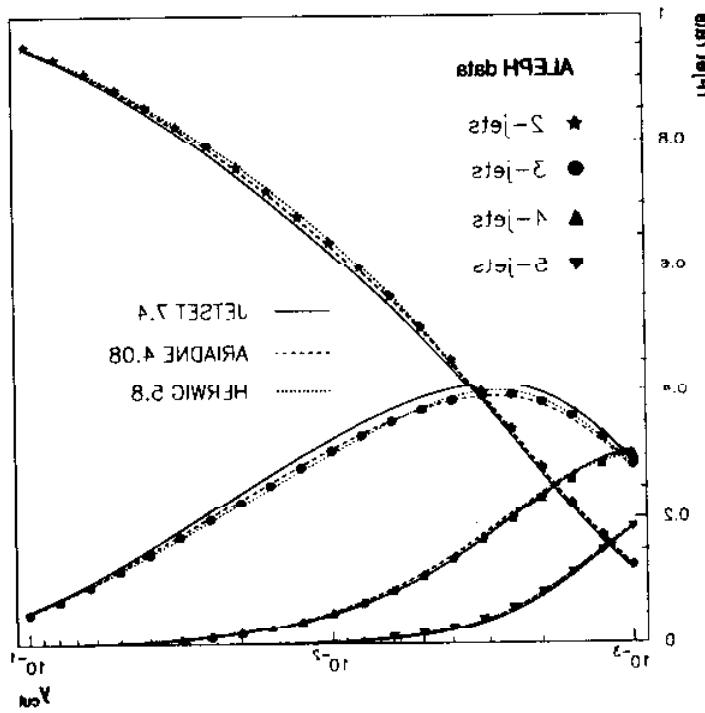
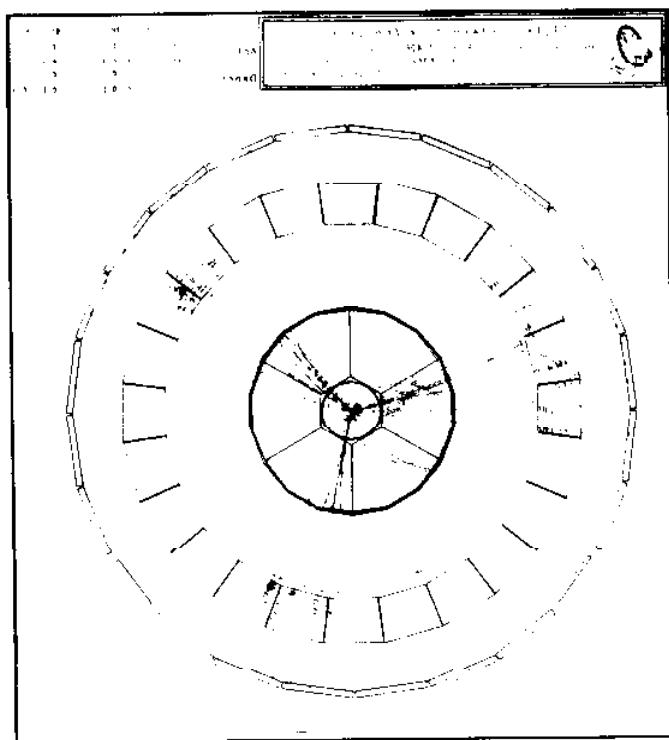
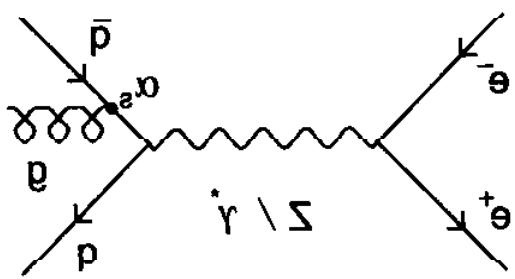
$$c = \sqrt{96\pi}/\beta_0 \approx 2.27$$



$$\alpha_s(M_Z) = 0.116 \pm 0.002(\text{stat.}) \pm 0.007(\text{sist.}) \pm 0.005(\text{theo.})$$

$$a = 0.070 \pm 0.008(\text{stat.}) \pm 0.014(\text{sist.})$$

## Q<sub>2</sub> from 3-jet tag

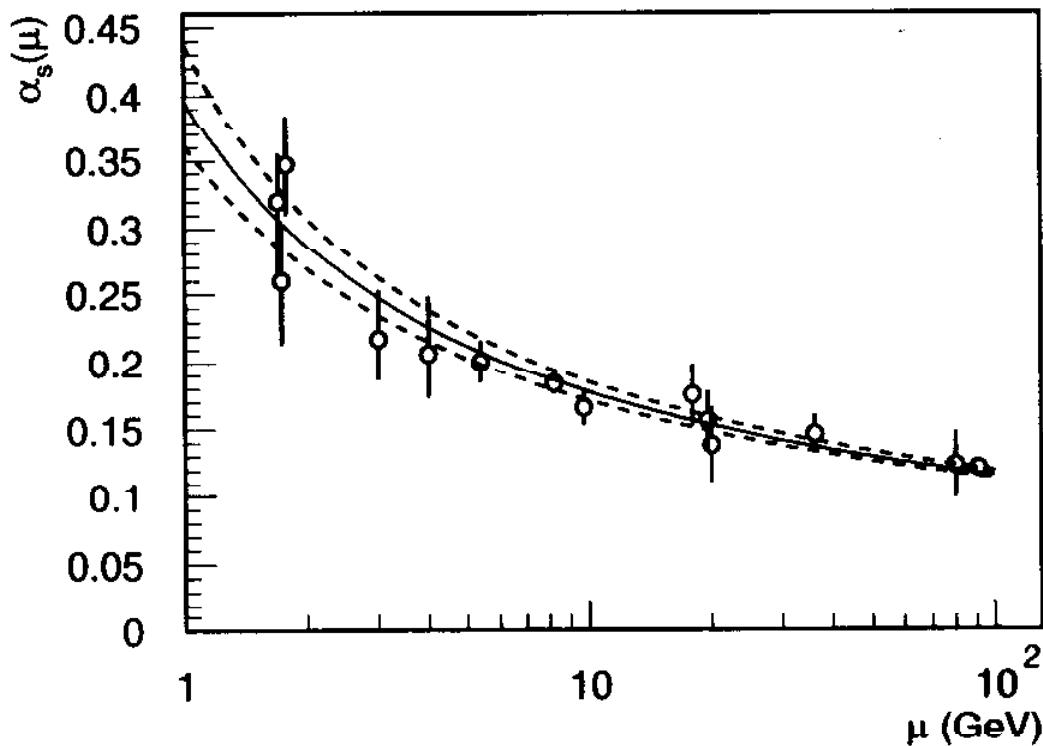


## Summary of $\alpha_s$ in LEP I

- $\sim 12$  million of hadronic  $Z$  decays  
( $\mathcal{L} = 0.3 \text{ mb}^{-1}$ )

$$\alpha_s(M_Z) = 0.121 \pm 0.005$$

## Status of $\alpha_s$ before LEP II



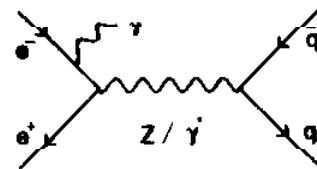
$$\alpha_s(M_Z) = 0.118 \pm 0.003$$

## $\alpha_s$ in LEP II

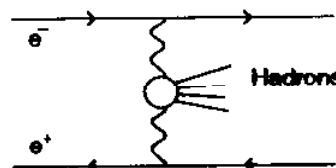
- small luminosity  $\sim 100 \text{ pb}^{-1}$

- new background source:

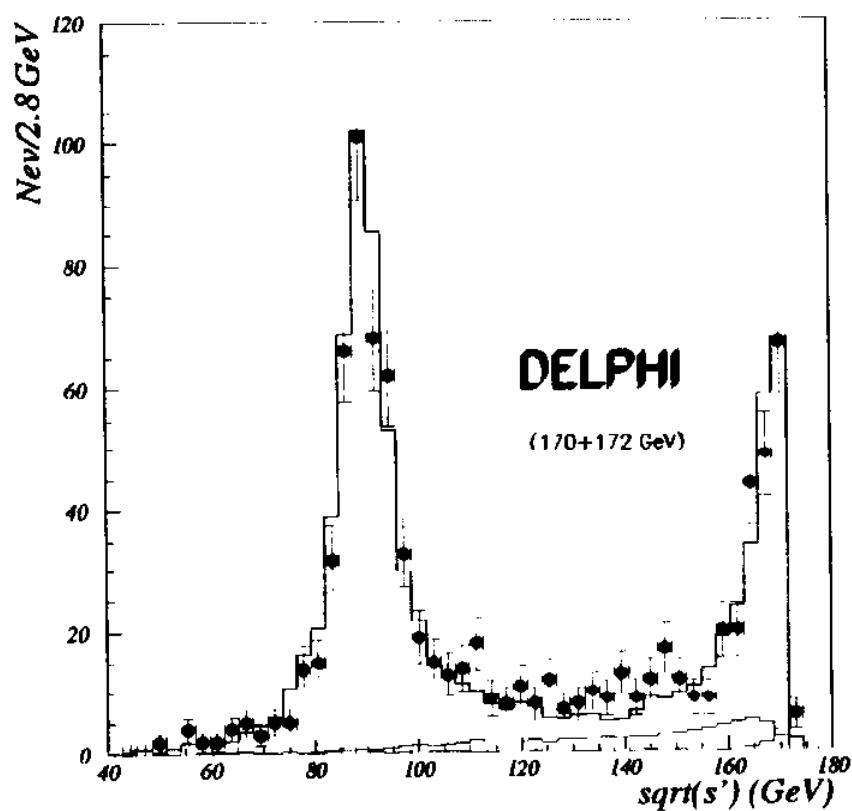
a) Radiative return to Z



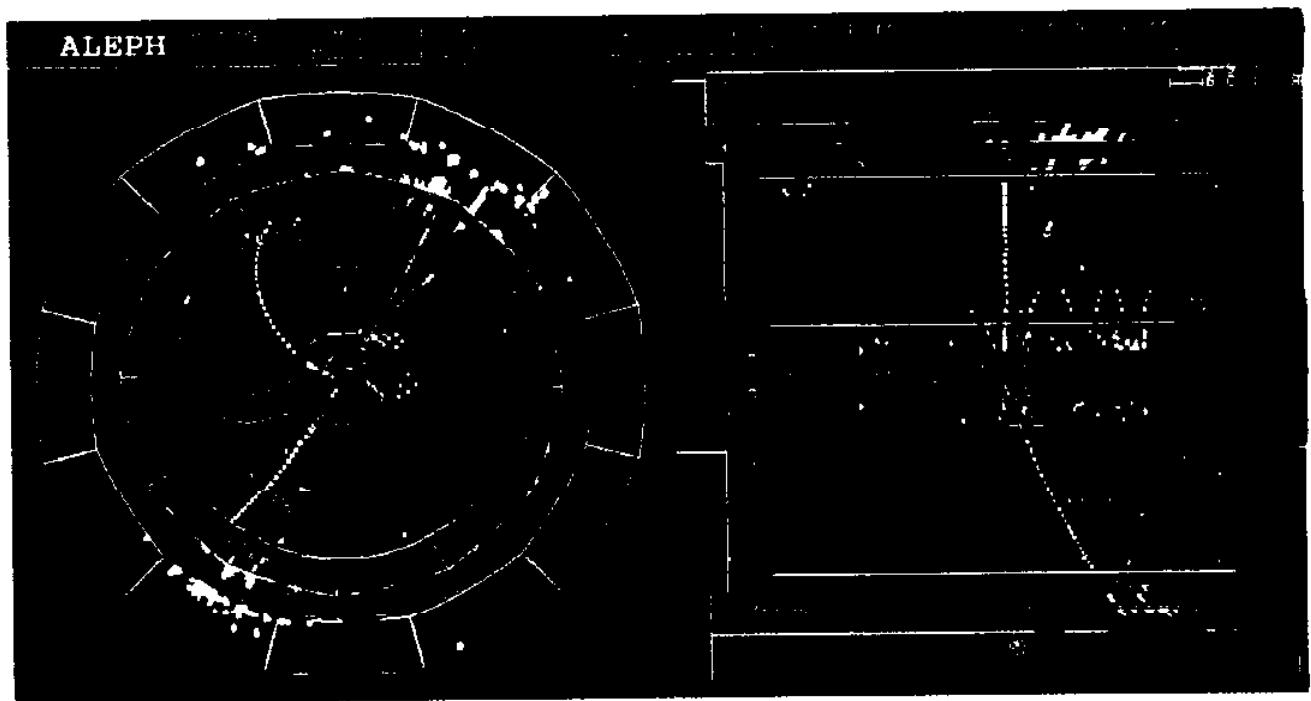
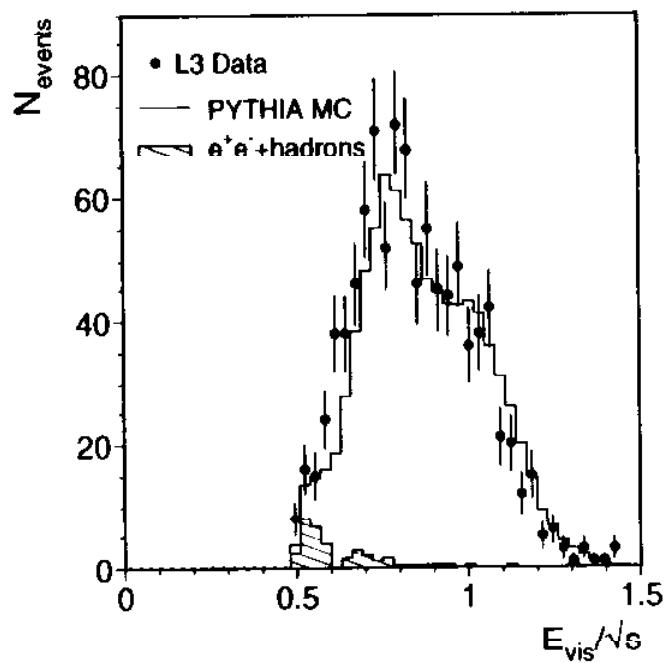
b)  $\gamma\gamma$  events



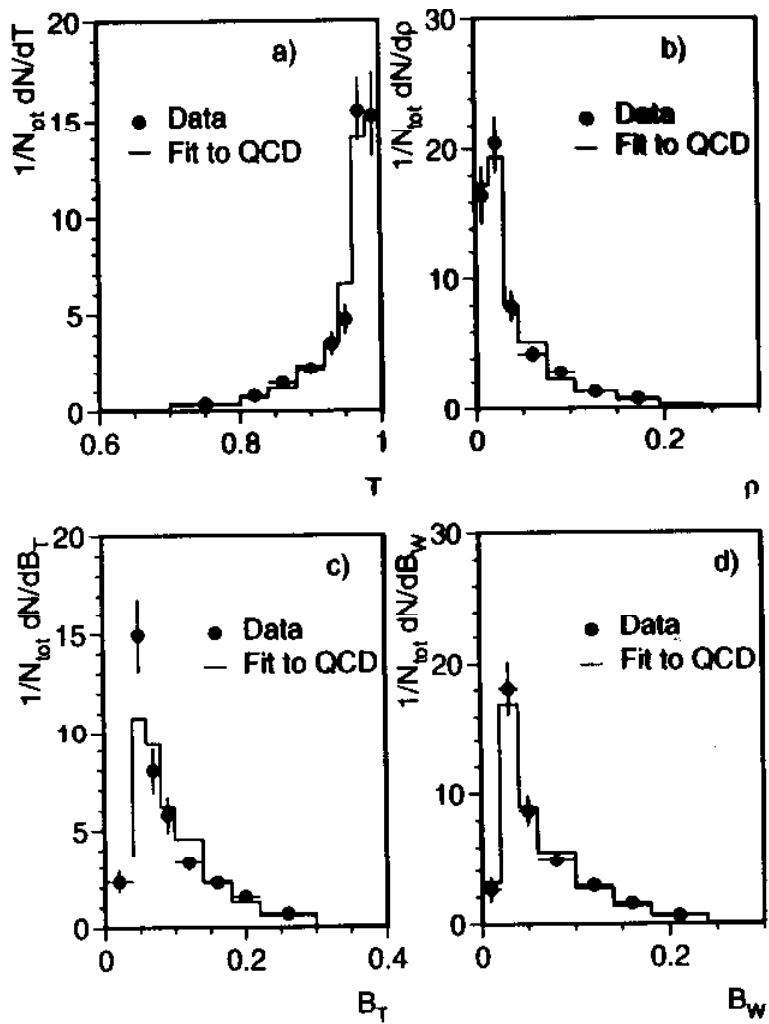
c) WW production (above threshold)



# Hadronic event selection at 130 GeV



# Event shapes at $\sqrt{s} = 130 \text{ & } 136 \text{ GeV}$

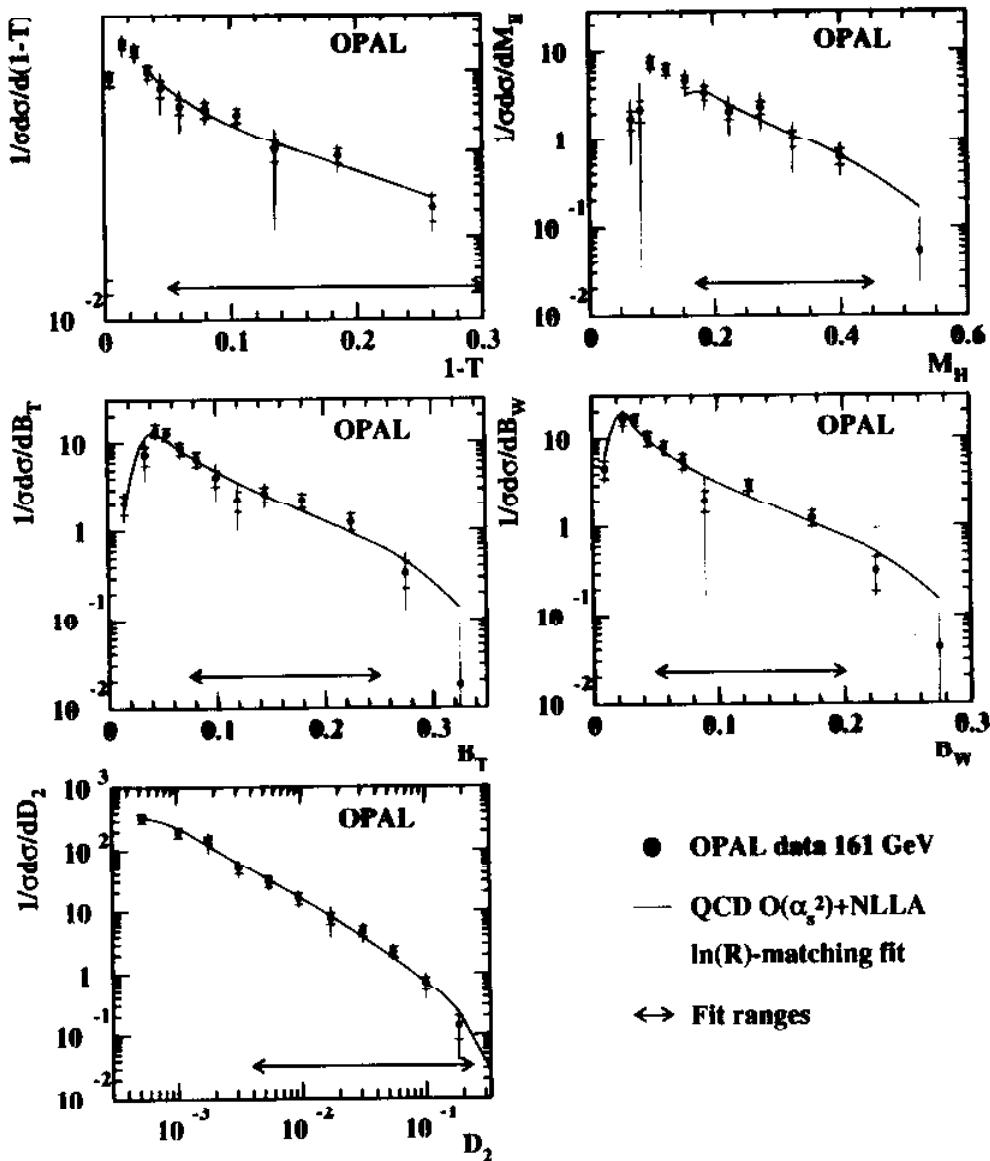


- L3: The sample consists on 402 hadronic events ( $\mathcal{L} \sim 5 \text{ pb}^{-1}$ )
- Resummed  $\mathcal{O}(\alpha_s^2)$  QCD calculations.

$$\alpha_s(133 \text{ GeV}) = 0.107 \pm 0.005 \text{ (exp.)} \pm 0.006 \text{ (theo.)}$$

# Event shapes at $\sqrt{s} = 161$ GeV

**Preliminary**



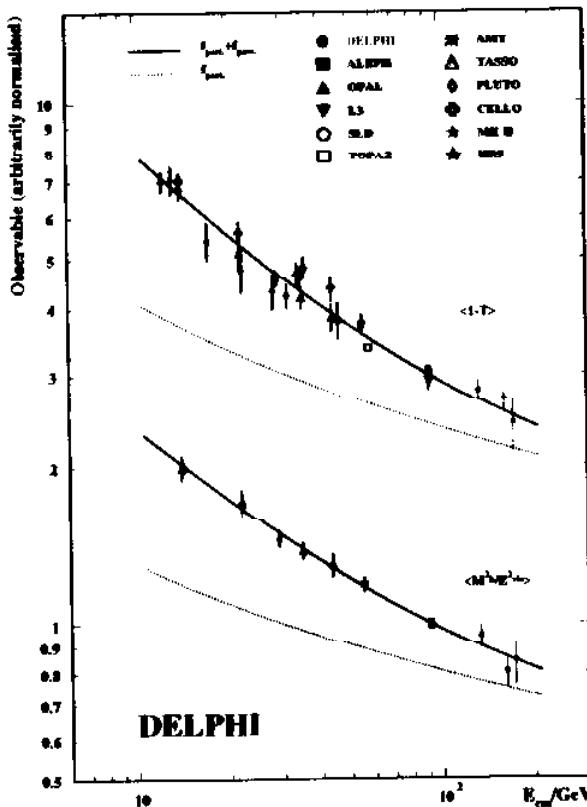
**OPAL:  $O(\alpha_s^2)$  + NLLA QCD**

$$\alpha_s(161\text{GeV}) = 0.102 \pm 0.005(\text{exp.}) \pm 0.007(\text{theo.})$$

# Fragmentation Model Independent $\alpha_s$ Determination

$$\langle f \rangle = \frac{1}{\sigma_{tot}} \int f \frac{d\sigma}{df} df = \langle f_{peri} \rangle + \langle f_{pow} \rangle$$

$$\langle f_{pow} \rangle = a_f \cdot \frac{\mu_I}{E_{cm}} \left[ \bar{\alpha}_0(\mu_I) - \alpha_s(\mu) - \left( b_0 \cdot \log \frac{\mu^2}{\mu_I^2} + \frac{K}{2\pi} + 2b_0 \right) \cdot \alpha_s^2(\mu) \right]$$



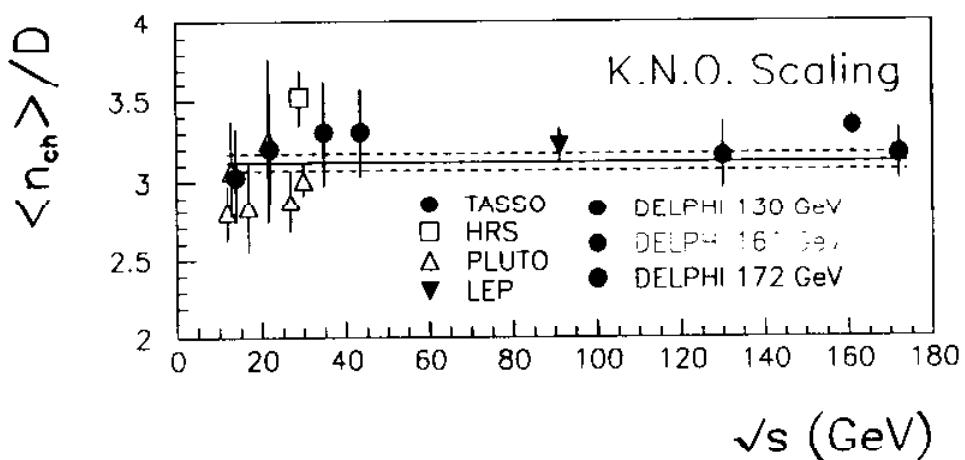
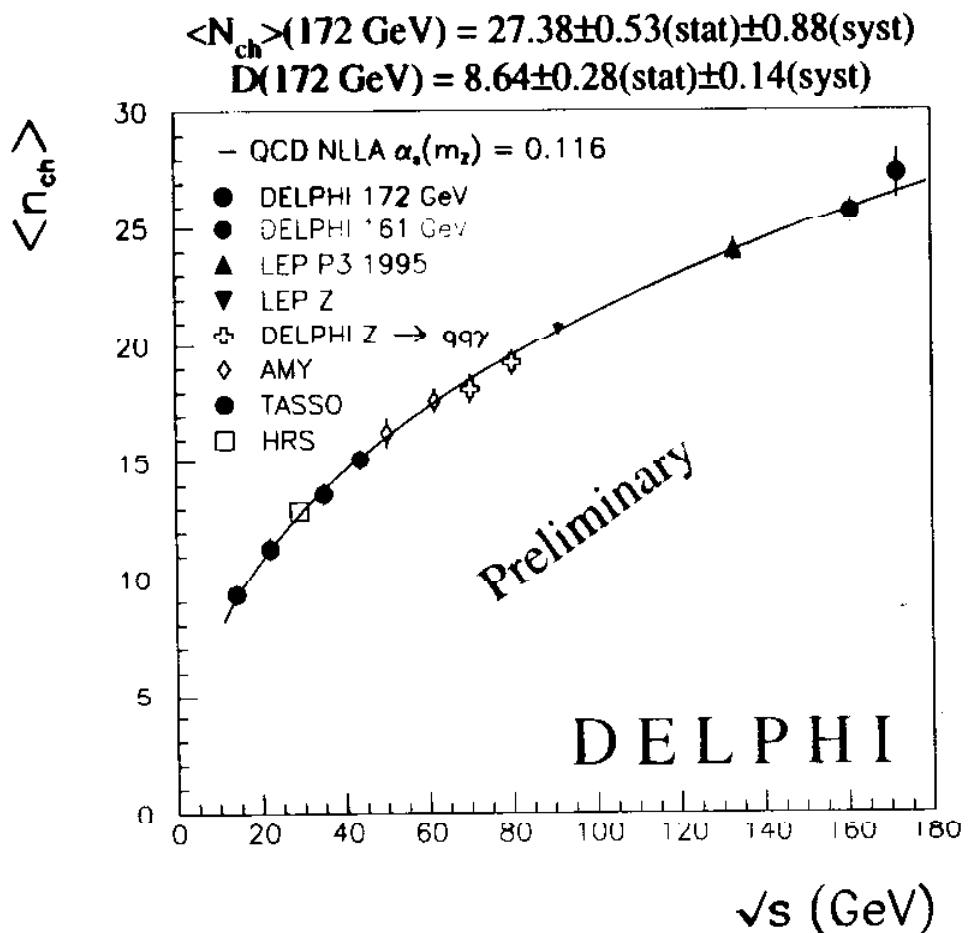
$$\alpha_s(133 \text{ GeV}) = 0.116 \pm 0.007_{exp}^{+0.005}_{-0.004}{}^{theo}$$

$$\alpha_s(161 \text{ GeV}) = 0.111 \pm 0.007_{exp}^{+0.005}_{-0.004}{}^{theo} \quad (\text{preliminary})$$

$$\alpha_s(172 \text{ GeV}) = 0.111 \pm 0.007_{exp}^{+0.005}_{-0.004}{}^{theo} \quad (\text{preliminary})$$

- The size of the non perturbative corrections decreases with  $\sqrt{s}$

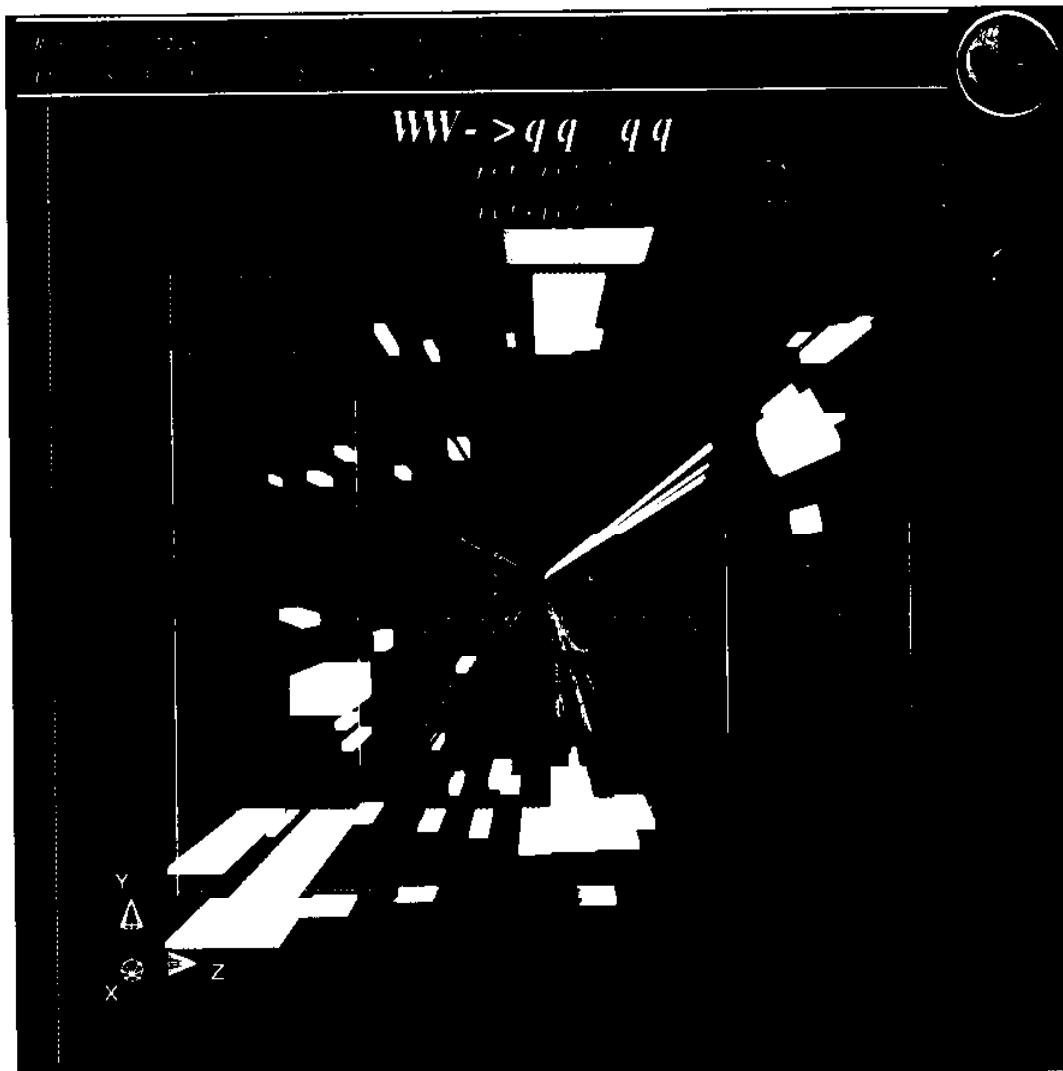
# Charged multiplicity at LEP II



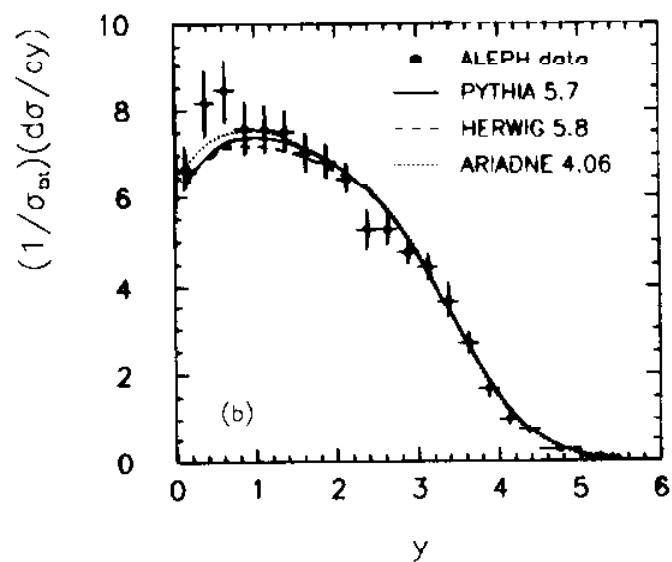
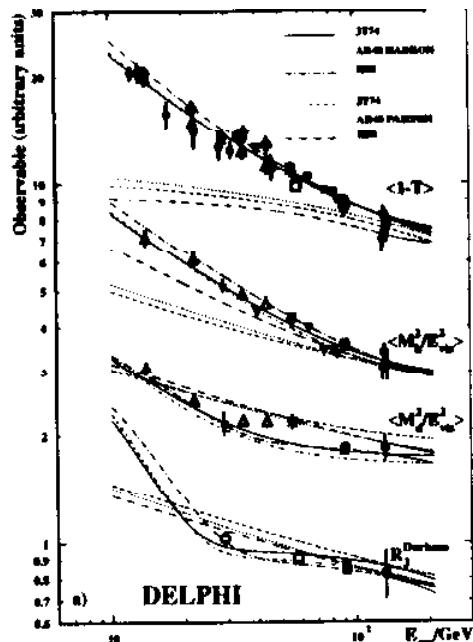
V

## WW background

$\Rightarrow 2\% \sim 5\%$  of the total hadronic sample



# Event shapes at $\sqrt{s} = 130$ & 136 GeV



- DELPHI  $\mathcal{O}(\alpha_s^2)$  + NLLA

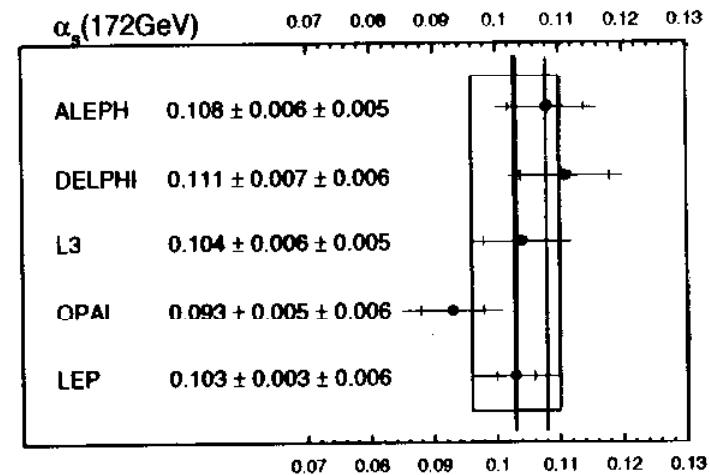
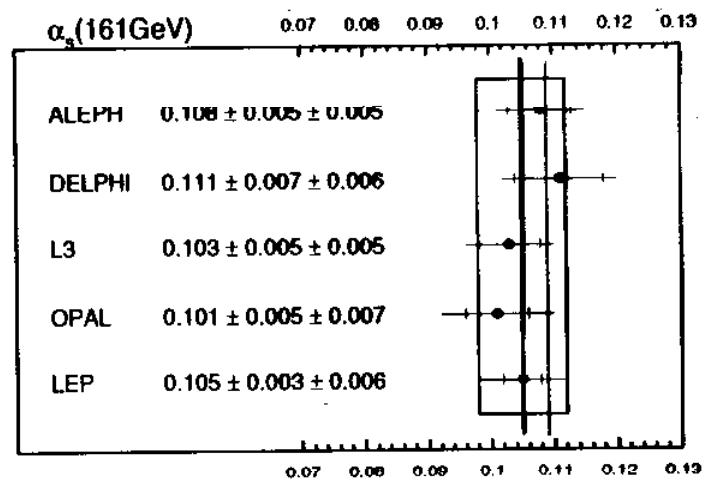
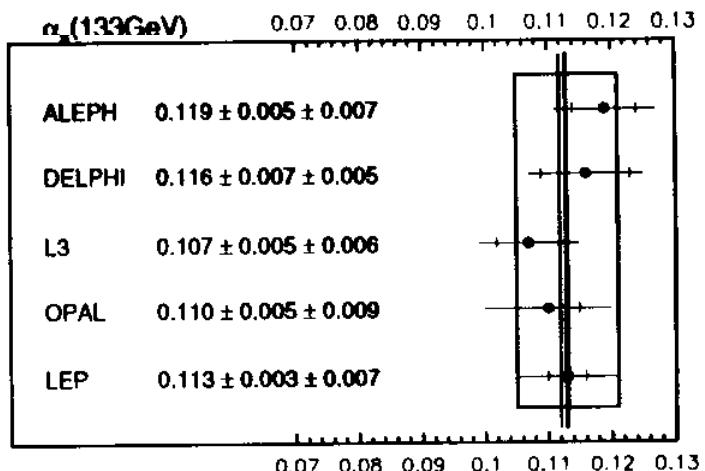
$$\alpha_s(133 \text{ GeV}) = 0.116 \pm 0.007 \text{ (exp.)}^{+0.005}_{-0.004} \text{ (theo.)}$$

Observable	$\alpha_s(M_Z)$	$\chi^2/ndf$
$\langle S \rangle$	$0.173 \pm 0.004$	10.9/6
$\langle 1 - T \rangle$	$0.123 \pm 0.002$	42.7/27
$R_3^{Durham}$	$0.137 \pm 0.019$	1.80/3
$R_3^{Jade}$	$0.123 \pm 0.002$	7.99/13
$\langle \frac{M_h^2}{E_{vis}^2} \rangle$	$0.116 \pm 0.006$	6.30/9

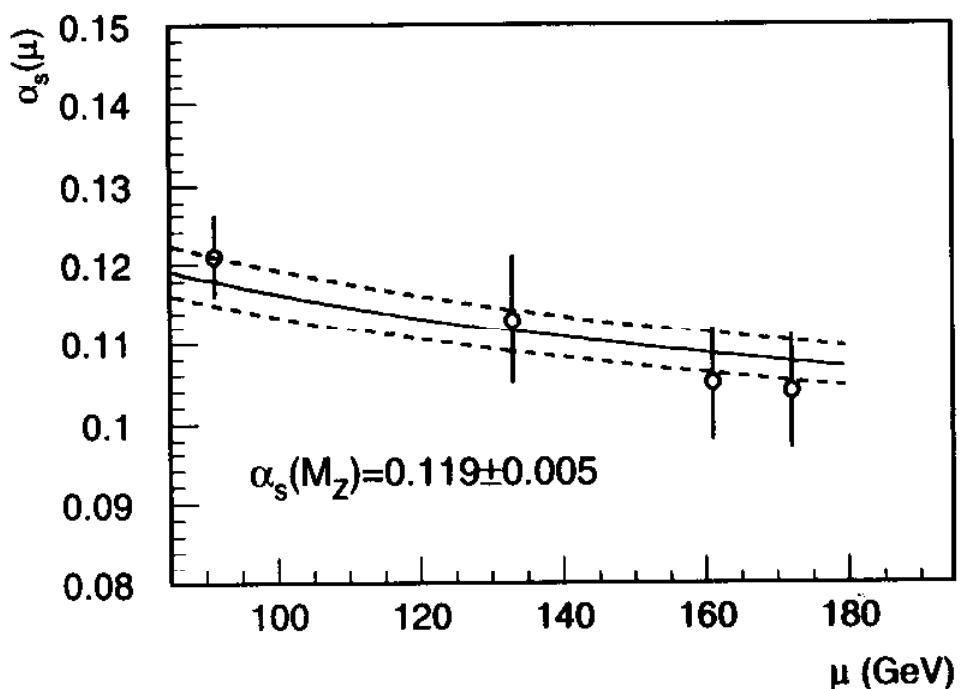
- ALEPH Differential two jet rate:

$$\alpha_s(133 \text{ GeV}) = 0.119 \pm 0.005 \text{ (exp.)} \pm 7 \text{ (theo.)}$$

## Summary of $\alpha_s$ at LEP II



## All LEP measurements:



## All $\alpha_s$ measurements:

